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Research Article

Open reduction and Salter innominate osteotomy combined with femoral osteotomy in the treatment of developmental dysplasia of the hip: Comparison of results before and after the age of 4 years

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ABSTRACT

Objective: This study aimed to compare the clinical and radiological findings of radical reduction (open reduction and Salter innominate osteotomy combined with femoral osteotomy) for children of walking age, younger and older than 4 years in the treatment of with developmental dysplasia of the hip (DDH).

Methods: In this retrospective study, children of walking age with DDH who underwent radical reduction between 2008 and 2014 were identified. They were then divided into 2 groups according to the age at which the surgery was performed: before and after the age of 4 years. Improvement in the acetabular index was examined on follow-up radiographs. The presence of avascular necrosis (AVN) was determined and classified on the basis of the Kalamchi-MacEwen classification on final follow-up radiographs. Clinical assessment was performed with the modified McKay criteria at the final follow-up appointment.

Results: A total of 19 children (14 girls, 5 boys; mean age=37.5±21 months) (25 hips) were included. Their mean age was 27.9±4.9 and 63.3±19.7 months in children operated before and after the age of 4 years, respectively. The mean follow-up time was 29.9±19 and 19.6±5 months in children operated before and after the age of 4 years, respectively. No significant difference was observed in improvements in the acetabular index between children younger than 4 years (24±6.9°) and those older than 4 years (20.7±6.7°) (p=0.25). According to the modified McKay criteria, all the children younger than 4 years exhibited excellent or good clinical results compared with those operated after the age of 4 years (67%) (p=0.013). At the final follow-up, 64% of all patients demonstrated no radiographical sign of AVN. The rates of AVN were significantly higher in children operated after the age of 4 years (33%) than in those operated before the age of 4 years (19%) (p=0.049).

Conclusion: Better clinical and radiographical results can be expected from radical reduction in children undergoing surgery before the age of 4 years.

Level of Evidence: level III, Therapeutic Study

Introduction

It is known that the normal development potential of the hip joint is the highest at birth, after which excellent potential exists till approximately 18 months. İn patients with developmental dysplasia of the hip (DDH), conservative treatment is inadequate and surgical intervention is required to avoid lasting deformities (1, 2).

It has been proposed that the goal in the management of DDH must be to reconstruct the anatomical structure and provide the function as close to normal as possible (3, 4). A generally accepted view is that absolute concentric reduction between the femoral head and the acetabulum is necessary for the management of the hip dysplasia. The goal of Salter osteotomy is to stabilize the hip joint in walking position, which is stable in flexion and abduction after reduction, by redirecting the entire acetabulum so that loading can be achieved and sufficient stimulation is provided for the bony development of the hip joint (5). According to Salter et al., the risk of avascular necrosis (AVN) of the femoral head increases owing to coexisting open reduction rather than innominate osteotomy (5). A reduction in the incidence of AVN has been established in patients older than 3 years who have undergone open reduction and femoral shortening (6). Vascular destruction has unfavorable effects on the ossification center of the femoral head and growth plate. This destruction causes growth defects in the femoral head and neck and the acetabulum. Kalamchi and MacEwen (7) have radiologically classified these changes. McKay (8) has clinically classified the patients per the clinical manifestations of pain symptoms, gait pattern, range of motion of the hip joint, and the result of the Trendelenburg test. Advanced operative age was previously shown to have poor outcomes in terms of clinical and radiological findings (9, 10).

This study aimed to evaluate the outcomes of radical reduction (open reduction and Salter innominate osteotomy combined with femoral osteotomy) in children of walking age with DDH requiring surgery before and after the age of 4 years. We tested the hypothesis that radical reduction performed before the age of 4 years would give more favorable results in terms of clinical radiological outcomes.

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Materials and Methods

We planned to evaluate the outcomes of surgery with radical reduction before and after the age of 4 years in children of walking age diagnosed with DDH who presented to the Mersin University, orthopedics and traumatology department, between 2008 and 2014. A total of 52 patients underwent this procedure during this period. The inclusion criteria were being older than 18 months, having received no treatment for DDH before, the presence of adequate file data, and no additional neurological disease. A total of 25 hips of 19 patients who met the criteria were eligible. The local research ethics committee approved the study.

The patients' age, sex, and pre- and postoperative and last follow-up pelvis anterior-posterior radiographs were collected from the medical records and digital system. The acetabular indices were measured from these radiographs. The hips were classified according to the Tönnis' classification from the preoperative radiographs (Table 1) (11).

In last follow-up radiographs, AVN of the hip was classified according to the Kalamchi-MacEwen classification (Table 2) (7). The clinical assessment results were noted in age groups according to the modified McKay criteria in their last follow-up examination (Table 3) (8). Clinical and radiological assessments were performed by 2 researchers (CK and MC). The digital picture archiving and communication system was used for radiological assessment.

Bikini and lateral-proximal femoral incisions were performed in all the patients. We first removed a triangular full-thickness bone graft from the anterior part of the iliac crest. Then, we performed the Salter osteotomy to the acetabulum using the Gigli saw. The ostetomy line was extended from the sciatic notch to the anterior inferior iliac spine. The distal fragment of the osteotomy line was grasped with a towel forceps and properly pulled down inferiorly, anteriorly, and laterally. The triangular bone graft was placed in the osteotomy line and fixed with the Kirschner wires. Because of excessive femoral anteversion, all the patients underwent derotation. In addition, we performed varisation osteotomy in all the patients to ensure concentric reduction. For the femoral osteotomy, a longitudinal mark was made with the saw along the anterior aspect of the femoral shaft. This served as an orientation mark for the femoral rotation. The degree of femoral derotation was determined intraoperatively by calculating the degree of femoral internal rotation, providing concentric reduction between the femoral head and the acetabulum during neutral position. The femur was transected just below the lesser trochanter. The hip was reduced, and the distal femoral shaft was aligned with the proximal shaft. The amount of overlap was noted and marked on the distal fragment. After the femoral shaft was transected again at that level and the rotation marks were aligned, the osteotomy site was fixated by dynamic compression or semitubular, Harris-Muller, or locked anatomical plates. Adequate decompression of the hip joint was controlled by applying moderate force and distracting the reduced femoral head 3 or 4 mm from the acetabulum. Spica casts, from nipples to malleoli on the operated side and to the knee on the other side allowing the feet free, were routinely applied postoperatively and removed 6–8 weeks later. In 1 patient with a late operation, a splint with pelvic support was applied. The patients were allowed to bear weight at the end of the second month according to the callus formation seen in the radiographs.

Statistical analysis

Data analysis was performed using the Statistical Package for the Social Sciences version 11.5 (SPSS Inc.; Chicago, IL, USA). For continuous variables with normal distribution, mean±standard deviation and minimum-maximum values were given as descriptive statistics, and 2 group t-tests were performed to compare the averages of the 2 groups. The descriptive statistics for categorical variables (surgery groups younger and older than the age of 4 years) are given as numbers and percentages, and the chi-squared test was used to show the relation between 2 categorical variables. To determine the significance of the ratio differences between the categorical variables with relation, 2 ratio test was used with the help of MedCalc 10.3.0 statistical package program. Statistical significance level (p) was taken as 0.05 for all analyses.

Results

Of the 19 patients who participated in the study, 14 (74%) were female and 5 were male (26%). In 6 patients, bilateral DDH was present. Of the 25 hips, 15 (60%) had right hip involvement and 10 (40%) had left

Table 1. The Tönnis' radiological classification (9)

Type 1	Femoral capital epiphysis medial to Perkins line and below Hilgenreiners line
Type 2	Epiphysis below Hilgenreiners line but lateral to Perkins
Type 3	Epiphysis lateral to Perkins line at the level of the acetabular margin
Type 4	Epiphysis lateral to Perkins line and above the acetabular rim

Table 2. The Kalamchi-MacEwen classification (7)

Type 1	Involvement of the femoral capital ossific nucleus
	Owingto a transient deficiency of the blood supply
	Normal head or slight loss of height
Type 2	Epiphysis and lateral physis involved
	Head in valgus with short lateral portion of neck
	Lateral growth plate may close prematurely
Type 3	Epiphysis and central physis involved
Type 4	Epiphysis and all of physes involved
	Coxabreva or coxavara
	Trochanteric overgrowth

Table 3. The Modified McKay criteria (8)

Class	Rating	Description
1	Excellent	Painless, stable hip; no limp; more than 15° internal rotation
2	Good	Painless, stable hip; slight limp or decreased motion; (–) Trendelenburg's sign
3	Fair	Minimum pain; moderate stiffness; (+) Trendelenburg's sign
4	Poor	Significant pain

Table 4. Demographic data and radiological evaluation of the hips (n=25)

	Age <4 years	Age >4 years
Age (months)	27.9±4.9*	63.3±19.7*
Follow-up time (months)	29.9±19	19.6±5
Preoperative acetabular index (degrees)	38.9±5.2	36.9±6.3
Postoperative acetabular index (degrees)	23.9±3.2	22.6±3.6
Follow-up acetabular index (degrees)	14.6±3.9	16.2±4.3
The Tönnis radiological classification (n, %)		
Type 1	-	-
Type 2	6 (37.5)	2 (22.2)
Type 3	8 (50)	2 (22.2)
Type 4	2 (12.5)*	5 (55.6)*

*p<0.05

HIGHLIGHTS

- Clinical and radiological improvement was worse in patients who underwent surgery for the developmental dysplasia of the hip at older than the age of 4 years.
- It is necessary to take initiatives to correct all the pathologies in theacetabulum, proximal femur, and soft tissues as much as possible in thetreatment of the developmental dysplasia of the hip.
- Radical reduction is a good treatment option in the appropriate age range, yielding excellent and good outcomes in patients with developmental dysplasia of the hip.

Figure 1. a-d. Radiographs of a patient (a) preoperative (b) 3 months postoperative (c) right hip 16 and left hip 11 months postoperative (d) right hip 36 and left hip 31 months postoperative

Table 5. Distribution of patient groups according to the Kalamchi-MacEwen classification

		Age	
		<4 years*	>4 years*
Type	0	13 (81%)†	3 (33%)†
	1	3 (19%)	3 (33%)
	2	0	2 (22%)
	3	0	1 (11%)
Total	16	9	

*p=0.031, †p=0.049

Table 6. Distribution of patient groups according to the modified McKay classification

		Age	
		<4 years*	>4 years*
Class	1	8 (62%)**	0**
	2	5 (38%)	4 (67%)
	3	0†	2 (33%)†
Total	13	6	

*p=0.013, **p=0.011, †p=0.027

hip involvement. The mean age of the operated patients was 37.5±21 months; mean follow-up time was 26.2±16.1 months. Mean interoperation time was 3.8 months (2-7 months) for those with bilateral operations (Figure 1). The descriptive data of the patients according to the age at which the operation was performed are given in Table 4.

Preoperative acetabular indices were 38.9±5.2 and 36.9±6.3 in patients operated before and after the age of 4 years, respectively (p=0.39). Mean corrections of the acetabular indices after the operation were also similar (24±6.9 vs. 20.7±6.7, p=0.25) (Table 4, 5).

Of the 16 hips operated before the age of 4 years, 2 (12.5%) were type 4 according to the Tönnis classification compared with 5/9 (55.6%) of the hips operated after the age of 4 years (p=0.046) (Table 4).

When the last follow-up radiographs were evaluated according to the Kalamchi-MacEwen criteria, 16 (64%) of the 25 hips were found to be normal; type 1, 2, and 3 AVN were detected in 6 (24%), 2 (8%), and 1 (4%) hips, respectively. The development of AVN was significantly and statistically higher in patients older than the age of 4 years (p=0.031). The incidence of grade 0 hip was statistically and significantly higher in patients younger than the age of 4 years (p=0.049). Distribution of patients according to the Kalamchi-MacEwen classification is given in Table 6.

Clinical outcomes according to the modified McKay criteria were statistically worse in patients over the age of 4 years (p=0.013). Excellent results according to the modified McKay criteria were statistically more frequent in patients under the age of 4 years (p=0.011). Fair results according to the modified McKay criteria were statistically more frequent in the over the age of 4 years group (p=0.027). Distribution of patients according to the modified McKay classification is given in Table 7.

A total of 2 of our study patients needed additional bone surgery. In 1 of the patients, deep wound infection was detected at 3 months postoperatively. After antibiotherapy was initiated immediately, the implants were removed at the 6th postoperative month. Owing to the loss of reduction at 10 months after operation, the patient underwent subtrochanteric shortening and derotation osteotomy to obtain concentric reduction. In another patient, proximal varisation derotation osteotomy was performed for the loss of reduction at 9 months postoperatively.

Preoperative, early, and last control postoperative radiographs of a patient with no AVN and excellent results are given in Figure 1.

Discussion

This study revealed that most of the patients with DDH who underwent radical reduction had excellent or good results. This study also showed that functional results and AVN rates in children operated before the age of 4 years are better.

Whether to perform femoral osteotomy in the same session with pelvic osteotomy has been argued. Salter et al. have stated that femoral osteotomy can be postponed until the age of 4 years because they believe that the femoral anteversion will improve over time after the pelvic osteotomy (12). Although Tachdjian has suggested postponing for anteversion up to 55°, Serafimov has emphasized that varus and derotation osteotomy should be performed when there is a 70° femoral anteversion and over 160° valgus deformity in the proximal femur (5,13). Yetkin (14) has stated that if excessive femoral anteversion is detected during open reduction, it should be corrected immediately. It is suggested that femoral osteotomy should be performed in combination with open reduction and Salter innominate osteotomy when there is excessive anteversion and valgus deformity, and it is also recommended that if femoral shortening is going to be performed after the age of 4 years, it should be performed simultaneously (5) as femoral shortening is important for a proper concentric reduction and a reduced AVN rate. However, varisation is mostly needed because of the excessive valgisation of the proximal femur (5). We performed open reduction combined with Salter innominate and femoral osteotomy in all our patients. In our patients with an average follow-up of 26.2 months, according to the clinical McKay classification, we achieved excellent and good results in 89.5% of them. Similarly, Haidar et al. have stated that they had good and excellent results according to the modified McKay criteria in 97.3% of patients in whom they had performed Salter osteotomy and open reduction for the treatment of DDH (15). Bhuyan et al. have reported in their study involving 30 patients that they had excellent outcomes in 13 and good outcomes in 14 patients who underwent radical reduction (16). When the last follow-up radiographs were evaluated, it showed

36% AVN according to the Kalamchi-MacEwen classification, of which 24% were type 1 AVN. These results showed that osteotomies that were performed simultaneously resulted in clinically good results and did not increase postoperative complications.

We found 23° correction in the acetabular index and clinically good and excellent outcomes in 89.5% of patients in accordance with the current literature. Improvement in the acetabular index was reported to be 16°-23.6°, and good and excellent clinical results were 71%-75% in the literature (17-20).

The acetabulum is composed of cartilage and labrum at birth. As the child matures, the acetabular epiphyseal centers develop and the majority of acetabular shape development is determined by the age of 8 years (21). The age of the patient is considered to be the primary factor affecting the outcome of treatment in DDH because the remodeling capacity of the acetabulum is known to decrease with age. According to the previous studies, clinical results and AVN rates were better in children operated before the age of 4 years (10, 12, 18, 22, 23). This was the reason for the cutoff age of 4 in this study. The poorest outcomes were observed for clinical, radiographic, and AVN results in patients diagnosed after the age of 8 years in the study by Ning et al. (9). The clinical and radiological results were worse in patients operated after the age of 8 years according to a study by Yağmurlu et al. (24). Zadeh et al. have performed open reduction in all their patients, and they tested the stability after the reduction (10). After the evaluation of the stability, they performed femoral osteotomy or Salter osteotomy. They have stated that patients who underwent surgery between the ages of 2 and 4 years developed less AVN radiologically than patients older than the age of 4 years. According to a study of Kınık et al. (25), with the radical reduction surgery described by Çakırgil in patients with DDH, 88% patients between the ages of 1.5 and 4 years, 77% patients between the ages of 4 and 8 years, and 53% patients after the age of 8 years were reported to have excellent and good results. In this study, mean age of the patients was 37.5 months. Macnicol et al. have performed combined open reduction and Salter osteotomy and reported that they received best outcomes in children younger than 30 months (26). Moulin et al. have performed open reduction and Salter ostetomy in all the patients and stated that after 24 months of follow-up, Salter innominate osteotomy should be performed in patients between the ages of 2 and 4 years and whose acetabular index is less than 40° (22). Mazloumi et al. have performed open reduction in all their patients (23). They performed Salter or Pemberton osteotomy depending on the femoral head size and acetabular capacity. They believed that the age of the patient and preoperative type of the hip according to the Tönnis classification are important factors in AVN of the femoral head. In their study, 13 of 17 patients who underwent surgery at younger than 4 years had good and excellent outcomes and 5 of 7 patients who underwent surgery when older than 4 years had good and excellent results. Kothari et al. have emphasized in their study that the lower the preoperative Tönnis grade, the better the outcome (27).

Gulman et al. have performed combined open reduction and Salter osteotomy and found that the best outcomes were obtained in patients between the ages of 1.5 and 4 years (18). In this study, 16 of the patients were between the ages of 1.5 and 4 years and 3 of them developed grade 1 AVN according to the Kalamchi-MacEwen classification. In 9 patients who underwent surgery at greater than the age of 4 years, 3, 2, and 1 developed grade 1, grade 2, and grade 3 AVN, respectively, according to the Kalamchi-MacEwen classification. This result proved that the risk of AVN development was lower in patients younger than 4 years. All patients who underwent surgery at younger than 4 years had good and excellent outcomes according to the modified McKay criteria. Good outcomes were obtained in 4 patients, and fair outcomes were obtained in 2 of 6 patients who underwent surgery when they were older than 4 years. None of the patients who underwent surgery at older than 4 years had clinically excellent outcomes.

This study had a number of limitations. It had a retrospective design with a relatively low number of patients and a short period of follow-up, particularly for the development AVN. All the patients were operated in the same center but by different surgeons. Clinical and radiological assessments were performed by 2 observers. Preoperative radiological evaluation of femoral anteversion as suggested by Mootha AK et al. was not performed (28). However, we believe that this study still adds to the clinical and radiological information about our area of research.

In conclusion, these results show that the clinical and radiological improvement was worse in patients who underwent surgery at older than the age of 4 years. Because of the progression of the pathologies and the reduced ability of remodeling with advanced age, it is necessary to take initiatives to correct all the pathologies in the acetabulum, proximal femur, and soft tissues as much as possible in the treatment of DDH. Radical reduction will be a good treatment option in the appropriate age range, yielding excellent and good outcomes in patients with DDH.

Ethics Committee Approval: Ethics committee approval was received for this study from the Clinical Research and Ethics Committeee of Mersin University in 30.04.2015-128.

Informed Consent: Informed consent was obtained from all the individual participants included in the study.

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